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THE COLONIAL RESEARCH COMMITTEE

THE inaugural meeting of the newly formed Colonial Research Committee was held at the Colonial Office on 29th June when the members of the Committee, eminent men of science, were addressed by the Secretary of State for the Colonies, the Right Honourable Viscount Cranborne. The Colonial Empire is expected to benefit greatly from the work of this Committee which will chiefly be concerned with the study of the application of science to colonial problems. Its primary function will be to advise the Secretary of State on schemes for assistance from the £500,000 a year which is provided under the Colonial Development and Welfare Act for "research and enquiry" but this, according to Viscount Cranborne will only be part of a wider function. "What is needed", he said, "is a broad survey of the whole range of research in Colonial studies. We need to know, first, what subjects ought to be studied, secondly, what is being done now, and thirdly, what can and should be done to fill the gaps. It seems to me that in several respects the field is not at present adequately covered. The older sciences have in this respect the advantage. We have now quite a long tradition, for instance, of the application of science to agriculture and health matters in the Colonies, though there is room even here for much more to be done in the way of pure rather than applied research. But there are newer sciences, less well organised perhaps, whose application to Colonial questions has not at present gone very far. Many of these could render work of immediate practical value to the Colonial Empire."

The £500,000 provided under the Colonial Development and Welfare Act is for the purpose of "research *and enquiry*". Viscount Cranborne laid special emphasis on the words "*and enquiry.*" "There will", he said, "undoubtedly be many applications from Colonial Governments for assistance in making enquiries that will be of immediate practical value to them—jobbing enquiries that the pure scientist may rather scorn to describe as research proper. I want to make it clear, however, that I very much hope that you will not scorn such enquiries. It was the intention of the Government that your field should include all forms of enquiry—the

ascertainment, collection and assessment of all facts that may be of value to the Colonial Empire. To quote the words of a well-known official report, we realize 'the duty of investigation and thought as a preliminary to action'."

The Committee was warned of the danger of thinking that only research which may have an immediate application to Colonial problems can be of value—an attitude to which all administrators are prone. Viscount Cranborne felt sure, however, that the Committee was in no danger of falling into that attitude. It is absolutely necessary for good and effective research that the research worker should preserve his intellectual freedom and although results of practical value are certainly hoped for it is equally hoped that the Committee will feel free to assist in the development of more fundamental research. Too much official control may easily devitalise research.

Referring to "Colonial studies" Viscount Cranborne said: "What are Colonial studies for the purpose of the scientist or the research worker? The term "Colonial" is surely misleading when we come to think about it. The Colonial Empire has so little uniformity. It is scattered all over the world and consists of peoples and countries of every kind and description. It has indeed been said that its only common factor is that it is British and that its affairs are dealt with by the Secretary of State and his Office in Downing Street. Apart from that, I can think of no quality that is common to all parts of the Colonial Empire. There are some that are common to large parts of it. For instance, most of the Colonies are in the tropics. All questions relating to tropical health or tropical agriculture or tropical engineering would therefore come within your purview. Again, most of the Colonies are engaged in primary production, in agriculture rather than in industry. All questions relating to primary production would therefore have an interest to the Colonial Empire. Again, most of the Colonies are maritime: they are interested in sea-borne trade; they are, or should be, interested in fisheries. Then, too, many parts of the Colonial Empire are inhabited by peoples who have only fairly recently come into contact with western civilisation. All questions relating to the development of such peoples and their relations with more advanced civilisations are therefore of interest to the Colonial Empire. Finally, there are large groupings of the Colonies geographically. There are, for instance, many Colonies in Africa. All scientific questions relating to Africa, and particularly to tropical Africa, would therefore come within your range of activities."

"It is clear that the members of the Committee will inevitably have contacts with many others, outside the Colonial Empire itself, working on problems which are yet of interest to the Colonies. Apart from institutions in this country, there are many in India and the Dominions, particularly perhaps South Africa, and many too in various foreign countries. The other Colonial powers, for instance, all have research institutions, which it is hoped in happier days after the war will exist again. We share many problems and can share too in their solution—the control of locusts, tsetse fly research, nutrition and so on. With the United States too we have already a long and happy tradition of collaboration on research matters. Scientific problems do not recognise national boundaries. They will assuredly provide, in the future as in the past, a fruitful field of international cooperation."

Referring to the coordination of research in Colonial studies the Secretary of State quoted the following from a letter received from one of the members who had been asked to serve on the Committee:

> "I have talked a good deal about cooperation and collaboration, but not . . . . about coordination . . . . Science is a free growth and as Sir David Chadwick recently wrote:—Much of the most valuable research must be free . . . . To many who rightly prize that characteristic of research, the word coordination denotes sinning against the Holy Ghost' . . . This warning must be remembered. Coordination is necessary within limits, to help to guide research into profitable channels and less waste, overlap or its converse may occur: but in dealing with a group of proud and independent nations, however friendly and cooperative, we and they must all beware of attempting to introduce a degree of direction, authority or control which many will certainly resent . . . . Cooperative research is a living growing organism, it must be carefully tended, it cannot just be pushed into a mechanical framework planned from outside."

These very wise words, although spoken primarily in connection with cooperation between the United Kingdom and the Dominions the Secretary of State fully endorsed as he thought they applied equally to the work that the Committee will have to do.

The members were assured that the setting up of the Committee would not restrict the freedom of action of those already engaged in research on Colonial matters. It was hoped, however, that the Committee will make it one of its objects to develop research work actually in the Colonial Empire itself. "There has been in the last twenty years or so a rapid development of the educational institutions in the Colonies. It is of great value to them that research work should be associated with them. There is an inevitable tendency for a university or any other institution for higher education in a young and growing country to become merely a factory for degrees or diplomas. The addition to such institutions of research workers, engaged primarily in the pursuit of pure knowledge without too

close a concern with its practical application, is of great value in fostering that atmosphere of learning that we associate with, for instance, our universities in this country."

There can be no doubt that the new Committee will play a very important part in the future development of research activities in the British Colonial Empire. It is just the kind of body which is at present so urgently needed to give advice, assistance and encouragement to the many existing agricultural, veterinary, medical and other research interests. As regards tropical agriculture it seems opportune here to refer to the very excellent work which has already been done for the Colonies by the Colonial Advisory Council of Agriculture and Animal Health. This body has during the past few years been largely responsible for guiding agricultural policy and research throughout the Colonial Empire. It has given invaluable advice on, and practical assistance in many agricultural and veterinary matters of vital interest to the Colonies, and we would go so far as to say that many of the advances made in agricultural and livestock research in the various Colonies have been stimulated by that Council. Its work has throughout proceeded very smoothly and it is hoped will long continue. The Colonial Research Committee, by following the excellent example set by the Council should, we feel, do as much for the general advancement of Colonial research as the Council has done for tropical agriculture.

REVIEW

THE MANUFACTURE OF INSULATION AND PRESSED BOARDS, WRAPPING-PAPERS AND STRAW-BOARDS FROM BAGASSE.

By M. P. Bhargava and A. N. Nayer, I.C.A.R. (India), Miscellaneous Bulletin No. 44. Published by the Manager of Publications, Delhi, India, 1941, price 2*s*.

The appearance of this bulletin dealing with the manufacture of insulation and pressed boards, wrapping-paper and straw-boards from bagasse is particularly appropriate just now, since the leading cane sugar manufacturers throughout the world are beginning to realize the possibilities of the by-products of their industry. For the purpose of this review, information given in the Bulletin will be considered in two sections (*a*) Technical, and (*b*) Commercial.

(*a*) *Technical Results*

Insulation and pressed boards occupy the greater part of the paper. The manufacture of insulation boards involves several operations. The most important are :—

(1) The preparation of the fibre stock.
(2) The formation of the boards.
(3) The drying of the boards.
(4) Chemical impregnation to render the boards moisture proof, fire-retardant, and immune to attacks of termites and fungi.

Operations (2) and (3), being standard procedures, were not investigated.

Experiments conducted on the preparation of the fibre stock and on the chemical treatment of the boards were successful. Both insulation and pressed boards were made, their properties comparing favourably with those of imported boards. The results of tests on the thermal insulating, sound absorbing, and static bending properties of the boards are tabulated in Appendices I and II. Details of the equipment and process used in the preparation of the boards are given, together with suitable illustrations.

Experiments were also carried out on the manufacture of wrapping-paper and straw-boards. It was shown that there were no serious technical difficulties in producing these from bagasse.

Samples of the various products are enclosed in a pocket at the back of the Bulletin.

(*b*) *Commercial Considerations*

It is estimated from the figures in Appendix III that the manufacture of insulating and pressed boards should be an extremely profitable undertaking, provided the internal market in India was not less than 1,600 tons. (1,000 tons of pressed boards and 600 tons of insulation boards).

About 2,400 tons of air-dry bagasse would be required. This could be obtained from the sugar industry wherein there are some six factories with a total surplus of 6,000 to 12,000 tons of bagasse. Unfortunately, estimates of the total imports of insulating and pressed boards to India at the time of the experiments were only 725 tons, or about 45 per cent. of the amount which would be produced by a commercial unit of the minimum size considered advisable. It was anticipated, however, that the consumption would increase rapidly in the near future. In fact it may have done so already.

The manufacture of wrapping-paper and straw-boards would have to be undertaken on a large scale, and sufficient surplus bagasse was not available. At the time of the experiments, therefore, it was not possible to consider the commercial production of any of the products discussed. It did appear, however, that the manufacture of insulating and pressed boards would become a commercial proposition as soon as the local consumption of these materials rose to 1,600 tons per annum.

The Bulletin is a useful contribution to our rapidly growing knowledge of how to produce valuable materials from the by-products of cane sugar factories.

R. D. E. Y.

NATURAL POLLINATION OF COCOA, *THEOBROMA LEIOCARPA*, BERN., ON THE GOLD COAST II

BY

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A previous paper (4) described an investigation of the pollinating agents of cocoa on the Gold Coast. Unidentified flying insects and a pollinating ant, *Crematogaster* (*Sphaerocrema*) sp. No. 1267, were shown to be responsible for setting under experimental conditions. The experiments were continued until the insect-proof cages were required for the expanding research on the swollen-shoot virus and, because of the limited staff available, it was decided to conclude pollination studies at the end of 1941. This paper records the results obtained from October 1940 to the end of the flowering period in September 1941.

Material

The same trees were used as in the earlier experiments; the tree numbers correspond to those in the first account (*loc. cit.*), and the description will not be repeated. The only changes were the inclusion of two more "control" trees to cover a wider flowering range, and the use of 30 mesh wire gauze and fine muslin only for the cages. Crawling insects were excluded from "banded" trees and cages by a concrete channel six inches wide and six inches deep, containing water.

TABLE I

Weekly Totals for Ten Control Trees 1940-41

High Flowering Periods.				Low Flowering Periods.			
Week ending 1941.	No. of flowers.	No. pollinated.	Per cent.	Week ending 1940.	No. of flowers.	No. pollinated.	Per cent.
Mar. 16 ...	39	—	—	Oct. 6 ...	20	4	20.0
23 ...	187	—	—	13 ...	5	4	80.0
30 ...	172	—	—	20 ...	5	1	20.0
Apr. 6 ...	169	8	4.7	27 ...	3	1	33.3
13 ...	108	13	12.0	Nov. 3 ...	4	2	50.0
20 ...	71	21	29.6	10 ...	3	0	—
27 ...	268	45	16.8	17 ...	4	3	75.0
May 4 ...	909	98	10.8	24 ...	10	3	30.0
11 ...	656	73	11.1	Dec. 1 ...	10	4	40.0
18 ...	630	48	7.6	8 ...	12	5	41.6
25 ...	356	32	9.0	15 ...	17	10	58.8
June 1 ...	312	71	22.7	22 ...	25	11	44.4
8 ...	484	75	15.5	29 ...	22	7	31.8
15 ...	941	125	13.3	**1941.**			
22 ...	960	123	12.8	Jan. 5 ...	28	12	42.8
29 ...	530	34	6.4	12 ...	14	4	28.5
July 6 ...	223	28	12.5	19 ...	6	2	33.3
13 ...	180	48	26.6	26 ...	1	1	100.0
20 ...	61	17	27.9	Feb. 2 ...	—	—	—
27 ...	118	18	15.2	9 ...	—	—	—
Aug. 3 ...	50	7	14.0	16 ...	—	—	—
10 ...	67	15	22.4	23 ...	—	—	—
				Mar. 2 ...	—	—	—
				9 ...	—	—	—
				Aug. 17 ...	50	23	46.0
				24 ...	41	7	17.1
				31 ...	19	10	52.6
				Sept. 7 ...	9	4	44.4
				14 ...	7	3	42.8
				21 ...	2	2	100.0
				28 ...	1	1	100.0
Total ...	7,491	899	12.0		318	124	39.0
Year Total ...	7,809	1,023	13.1				

Method

The trees were inspected each morning by Mr. L. Q. Reimmer, laboratory attendant, the newly-opened flowers counted, and any that remained on the tree more than four days, showing ovarian growth and style withering, were tagged as pollinated.

The efficiency of the pollinating ant *Crematogaster* (*Sphaerocrema*) sp. No. 1267, was the main object of the investigation. Nests of this ant in rotting wood were collected and placed in the branches of three caged trees which during the previous two years had given the very low pollination percentage already reported (*loc. cit.*), in spite of the presence of other species of ants and of aphids (*Toxoptera aurantii*) and psyllids (*Mesohomotoma tesmanni*). Colonies of apparently the same species of ant were also established on three banded trees, but it was found later that on two trees (Nos. 47 and 68) another species *Crematogaster* (*Acrocoelia*) sp. No. 1286* had been used. This ant closely resembles sp. 1267 (to which it is nearly related) in appearance and habits, and it proved to be only slightly less efficient at pollination.

* Quite distinct from *Crematogaster* (*Acrocoelia*) sp. No. 1295 shown in the previous paper not to be a pollinator.

Results

A comparison of Table I with Table II of the previous paper, which gives the pollination figures for the same trees for the preceding year, reveals the expected similarities in following seasonal trends. A remarkable similarity between the two years is the lack of pollination during March, recalling the "crazy flowering" in Trinidad, which Voelcker (5) has shown to be due to the lack of pollinating agents at this period. The writer suggested before (4) that the low humidity in March 1940 might be the direct cause of low setting, but this opinion must be reconsidered in the light of the 1941 results. Humidity was again lower in March than at any other time of year, but it will be shown that the lack of pollination was probably due to the inactivity of the ants, rather than to the direct effect of aridity on flower abscission.

As trees age they are producing more flowers, resulting in a lower percentage pollinated, just as fewer flowers are pollinated during a period of profuse flowering than when flowering is sparse.

Table II clearly shows the effect of the pollinating ant. Banded trees with colonies of the ant sp. No. 1267 and sp. No. 1286 were pollinated as effectively as control trees, but on trees from which these ants were excluded the

TABLE II

The Effect of the Pollinating Ant on Percentage Flowers Pollinated

TOTALS FOR YEAR OCT. 1940 TO SEPT. 1941

POLLINATION WITH ANTS.						POLLINATION WITHOUT ANTS.				
	Tree No.	No. of flowers.	No. pollinated.	Per cent.	Ant Sp. No.		Tree No.	No. of flowers.	No. pollinated.	Per cent.
Banded Trees ...	47	151	26	17.2	1286	Banded Trees ...	41	87	11	12.6
	68	191	33	17.3	1286		49	39	—	—
	138	152	35	23.0	1267		72	70	8	11.4
Total ...	—	494	94	19.0	—	Total	—	196	19	9.7
Caged Trees ...	19	602	23	3.8	1267	Caged Trees ...	25	159	—	—
	43	878	59	6.7	1267		57	811	1	—
	93	502	39	7.8	1267		122	96	—	—
Total ...	—	1,982	121	6.1	—	Total	—	1,066	1	,1
Control Trees ...	3	1,888	235	12.4	—					
	4	2,030	262	12.9	—					
	11	515	88	17.1	—					
	20	237	36	15.2	—					
	21	1,511	168	11.1	—					
	82	78	19	24.3	—					
	170	85	23	27.0	—					
	172	529	47	8.9	—					
	180	455	61	13.4	—					
	194	481	84	17.5	—					
Total ...	—	7,809	1,023	13.1	—					

percentage pollination was halved. The 9.7 per cent. pollination on banded trees without ants may be regarded as due entirely to flying insects, leaving another nine per cent. due to ants on those banded trees with ant colonies (sp. No. 1286, which was used in error, appears to be slightly less efficient than the closely related sp. No. 1267).

The caged trees with ants (sp. No. 1267) showed six per cent. pollination, those without ants negligible pollination, although aphids and psyllids were present most of the time. Comparison with the 13 per cent. pollination on control trees, which produced roughly the same average number of flowers per tree, indicates again that the ant is responsible for about half the pollination.

Table III shows that when the trees with ants flowered, pollination occurred more often than not. In contrast, trees from which ants were excluded, even the banded trees open to flying insects, more often flowered without being pollinated than with pollination. The most frequent occurrence of pollination was on the control trees, which is probably accounted for by the difficulty of maintaining an adequate ant population continuously on the caged and banded trees. The low frequency of pollination on the banded trees without ants, which nevertheless had 9.7 per cent. of their flowers pollinated, indicates that the flying insect is an efficient pollinator but of spasmodic occurrence.

These experiments provide no support for the views expressed by Voelcker (6) and Billes (1) that aphids are important pollinators. As already suggested (2), aphids may act indirectly by attracting an ant colony to the tree and individual ants to the flowers, but they have not been an essential factor in pollination by ants; pollination occurs in cages without aphids and with only the ant sp. No. 1267 present, but rarely occurs with aphids together with other species of aphid tending ants (4).

The lack of pollination in March 1940 which, as already mentioned, was repeated in March 1941, was probably due to the inactivity of the pollinating ant at that time. As shown in Table IV, hand pollination during this period was quite effective, despite the low humidities, which were lower during March in all three years, than at any other time of year. In the cages also where humidity does not fall so low, pollination

TABLE III

The Effect of the Pollinating Ant on Frequency of Pollination

TOTALS FOR YEAR OCT. 1940 TO SEPT. 1941

POLLINATION WITH ANTS.				POLLINATION WITHOUT ANTS.			
No. of weeks when tree flowered.				No. of weeks when tree flowered.			
	Tree No.	With pollination.	Without pollination.		Tree No.	With pollination.	Without pollination.
Banded Trees ...	47	16	16	Banded Trees ...	41	8	15
	68	11	8		49	0	13
	138	13	8		72	5	10
Total ...	—	40	32		—	13	38
Mean ...	—	13.3	10.7		—	4.3	12.7
Caged Trees ...	19	13	26	Caged Trees ...	25	0	20
	43	18	14		57	1	28
	93	18	0		122	0	15
Total ...	—	49	40		—	1	63
Mean ...	—	16.3	13.3		—	.3	21.0
Control Trees ...	3	35	7				
	4	34	6				
	11	18	7				
	20	16	6				
	21	24	8				
	82	11	4				
	170	13	6				
	172	13	10				
	180	15	8				
	194	20	6				
Total ...	—	199	68				
Mean ...	—	19.9	6.8				

TABLE IV

Hand Self-Pollination in March

Week ending	No. flowers pollinated.	No. set.
1941.		
March 16 ...	1	1
23 ...	2	2
30 ...	9	5
April 6 ...	75	57
1942.		
March 8 ...	18	8
15 ...	—	—
22 ...	99	28
29 ...	50	28
April 6 ...	18	15
Total ...	272	144

TABLE V

Natural Pollination in 3 cages with Ant No. 1267 in March

Week ending	No. flowers open.	No. pollinated.
1941.		
March 16 ...	55	0
23 ...	132	0
30 ...	91	0
April 6 ...	26	3
1942.		
March 8 ...	192	0
15 ...	139	2
22 ...	81	11
29 ...	61	0
April 6 ...	40	2
Total ...	817	18

NOTE.—For natural pollination on control trees in 1941 *see* Table I.

did not occur during March (Table V) even in the presence of the pollinating ant, and it was noticed that the ants were inactive at this period and remained in their nests more than usual instead of crawling incessantly about the trunk and flowers. This inactivity was noticeable only during the March period and may be attributed to unfavourable conditions. With this exception the pollinating ants appear to be responsible for constant pollination amounting to about half the total pollination throughout the flowering season. The flying insects, still unidentified, are more efficient but are not present continuously and cause about half the total pollination in spasmodic bursts.

Most, if not all, of the pollination by ants is probably self-pollination; most of that effected by flying insects may be cross-pollination, but it seems probable that crossing does not exceed half the total pollination. Voelcker (6) in Nigeria has estimated cross-pollination at 25 per cent. of the total. These low estimates fit in with the low yield obtained from self-incompatible trees, even when surrounded by self-compatible trees which could supply them with compatible pollen (3). The policy of discarding all self-incompatible trees from the Gold Coast selection list is therefore justified.

Summary and Conclusions

1. The continuation of experiments has confirmed that an ant *Crematogaster* (*Sphaerocrema*) sp. No. 1267, is an important pollinating agent of *Theobroma leiocarpa*, Bern., on the Gold Coast.

2. A closely related ant, *Crematogaster* (*Acrocoelia*) sp. No. 1286, is also shown to be a pollinating agent.

3. The results indicate that ants are responsible for about half the pollination effected, while unidentified flying insects account for the other half. Aphids are not pollinators of any significance.

4. The inactivity of the pollinating ants probably accounts for the low pollination during periods of low humidity (March).

Acknowledgments

The writer is indebted to Mr. G. S. Cotterell, Entomologist of the Department of Agriculture for obtaining from the Imperial Institute of Entomology the identification of ants used in these experiments, and to Mr. H. B. Waters, Director of Agriculture, for permission to publish this paper.

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GUATEMALA GRASS AS A FODDER CROP IN ST. LUCIA

BY

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From the time of its introduction into St. Lucia, about 1928, Guatemala Grass (*Tripsacum laxum*) has shown great promise as a fodder crop; field observations in those areas where plantings have been made show that, under reasonable conditions, the grass is able to cope successfully with the shortcomings of local practice; it grows quickly and easily, can survive for a considerable period without manuring and is able at all times to give what appears to be a good yield of palatable green fodder; in addition, its possibilities as an erosion control agent must not be ignored. The trial described below was conducted, in part, approximately along the lines of present local practice; the results should encourage the extension of Guatemala grass as a soiling crop for rotational cutting in the Colony.

The site chosen for the experiment was a level area previously under semi-abandoned citrus and avocado cultivation; the soil, a brown alluvial loam, has been described by Croucher (1) as somewhat low in humus, naturally acidic—pH around 6.5—and giving indications of a ready response to small applications of potash and phosphate fertilisers. A Latin square layout was adopted with the following per acre treatments in two small 4 by 4 squares with plots approximately 1/132 acres in size:—

1. Pen Manure, 10 tons.
2. Pen Manure, 10 tons. } Sulphate of Ammonia, 1 cwt. }
3. Sulphate of Ammonia, 2 cwt.
4. Sulphate of Ammonia, 1½ cwt., } Muriate of Potash, 1 cwt., } Superphosphate, 1 cwt. }

The land was thoroughly forked and drained, with 12-inch drains separating the plots; root divisions comprising two- and three-tiller sections were used, spaced two feet by 1½ feet; planting was done "on the flat" but it is now considered that it might have been better to plant in furrows; further reference will be made to this point. Planting was done in October 1939; some supplying was necessary and a full stand was obtained by December; manures were applied in March 1940 and cutting commenced in mid-April. One complete row of four treatments was cut every week, giving a cutting rotation of eight weeks; stools were cut at approximately nine inches from ground level, and all material was weighed immediately after cutting. Weekly cuttings were continued to the end of August 1941, covering a period of 72 weeks, when the experiment had been cut over nine times; the results are presented in Table I.

(1) *Vide* Summary in *Annual Report, Department of Agriculture, St. Lucia*, 1929.

TABLE 1

Yield of Green Herbage

Treatment.	1	2	3	4	Mean.
Mean yield for a total of 9 harvests:—					
(*a*) lb. per plot	728.75	727.12	702.37	719.25	719.37
(*b*) tons per acre ...	42.93	42.84	41.31	42.39	42.39
(*c*) per cent. of General Mean ...	101.30	101.07	97.63	99.98	100.00
Mean yield per cutting:—					
(*a*) lb. per plot ...	80.97	80.79	78.04	79.91	79.93
(*b*) tons per acre ...	4.77	4.76	4.59	4.71	4.71

The treatment differences in these results are obviously not significant. This was only to be expected as although each treatment represented a distinct type and rate of manuring, with only one application at the beginning of a 72 week experiment there was no great difference between the treatments in total quantity of fertiliser applied. What is of interest, however, is the mean yield of 4.71 tons per acre per cutting which, under the conditions of the experiment, represents an annual yield of 30.61 tons per acre. No damage by insects or fungi was noticed during the period of the trial.

Table 2 shows the monthly rainfall over the cutting period, together with the mean monthly yields of green fodder expressed as tons per acre.

TABLE 2

Month.	1940.		1941.	
	Rainfall ins.	Yield t.p.a.	Rainfall ins.	Yield t.p.a.
January ...	2.02	—	1.79	3.10
February ...	1.26	—	0.43	1.55
March ...	3.87	—	4.13	1.57
April ...	1.89	5.70	3.67	1.99
May ...	3.01	8.57	4.19	2.07
June ...	7.35	6.32	5.23	2.50
July ...	7.39	9.30	10.94	2.80
August ...	13.06	7.75	9.42	2.87
September ...	6.70	6.90	—	—
October ...	6.27	6.05	—	—
November ...	10.29	5.92	—	—
December ...	2.89	4.42	—	—

The mean yield per cutting over the five months April to August, was 7.53 tons, but for the corresponding months in the succeeding year it had fallen away to 2.45 tons. In fact, if one makes allowance for variation in monthly rainfall, it can be stated that after the first four months there is a steady drop in the yields of herbage. There can be little doubt that small though regular applications of manure would have shown a different picture; the need for regular manuring throughout the trial was fully appreciated, but as the original intention had been to keep in line with local practice such needs had to give place to the question of first demonstrating the value of the grass at existing levels of cultural practice in the hope of encouraging its cultivation. After this it was considered that the introduction of an improved cultural practice would follow with greater ease.

It has already been suggested that planting in furrows might have been better than flat planting; actually one reason for terminating the records after only nine complete cuttings was the large number of gaps caused by stools that had grown above the surface of the ground and then succumbed during dry spells or to overturning by wind; in many cases also the process of cutting tended to uproot the stools and, although the original planting distance was found to be adequate for weed control, the many gaps that opened-up were rapidly invaded by weeds. This high stool mortality is probably in part responsible for the drop in yield with successive harvests. By cutting back the stools to ground level periodically as suggested by Paterson (2) instead of taking every harvest at nine inches high, the stool mortality might have been reduced, especially if the original planting had been in shallow furrows followed by a subsequent moulding up of the soil against the rows of the standing grass. This question of obtaining a relatively deep-rooted and firmly established stool is of particular importance in the case of Guatemala Grass, for while it is a very persistent fodder crop when the cultural practice is sound, it has this tendency to become uprooted where the field conditions are not correct. The question of whether adequate furrows could be made at the spacing of two feet recommended by Paterson (2) or whether three foot rows with only one foot between stools in the row would be more feasible is worthy of investigation; the latter spacing would make for easier intercultivation, and should facilitate weed control.

The foregoing has dealt with planting on level land, but such land is at a premium in St. Lucia; on sloping land contour furrows would naturally be used, and field observations have indicated that, when thus planted at say one foot spacing along the row, Guatemala Grass would find added use as a strip-crop for combined fodder production and soil-erosion control; there is urgent need for both these practices in St. Lucia. The tendency of Guatemala Grass to develop a superficial root system prevents it from being perfect for erosion control, but in practice it has proved satisfactory.

(2) Paterson, D. D., *Emp. Jour. Exptl. Agric.*, VI, 24, 1938, and certain articles mentioned in the list of references annexed thereto.

Summary

An experiment with Guatemala Grass, laid down in 1939 on an alluvial soil of medium fertility is described; simple manurial treatments showed no significant differences, but with a cutting rotation of eight weeks and extending over nine rotations a mean yield of 4.71 tons per acre per cutting was obtained, equivalent to 30. 1 tons per acre per annum; yields fell rapidly as the trial progressed due, apart from seasonal rainfall variation, to the fact that in accordance with present local practice only one initial manuring was given.

It is suggested that planting in furrows is preferable to flat planting in order to obtain a more firmly established stool; a furrow spacing of three feet, with stools at 1 to 1½ feet in the row, might be more feasible than using a 2 by 1½ foot spacing.

From its behaviour under the conditions of the experiment, and from field observations in other planted areas, Guatemala Grass is recommended as a dual fodder and erosion-control crop for contour strip planting on sloping land; it can thus contribute to the solution of two of St. Lucia's most urgent agricultural problems.

Acknowledgment

To Mr. E. T. Ward, Agricultural Superintendent, grateful acknowledgment is made for his share in this work and his continued interest therein.

STRIP WEEDING IN COFFEE

A. J. Sinclair in the *Mon. Bull. Coffee Bd., Kenya*, 1942, **7**: 8, 4. records a system of erosion control used on his coffee plantation in Kenya. Instead of cultivating through the whole plantation which might take six weeks, he cultivates alternate strips, i.e., down one side of the tree in the first instance. The strips left unweeded act as erosion barriers against heavy rains. By the time the return journey down the still uncultivated side is started danger of heavy rain has ceased. It is claimed also that there is less danger of checking the tree since any root injury caused by cultivation on one side will be on the way to being repaired by the time the other side is reached. The value of the method to various Kenya Soil types is the subject of a note by Mr. V. A. Beckley, Senior Agricultural Chemist, who points out that in some cases mechanical reinforcements to hold up the run off would be necessary.—(*Horticultural Abstracts*, XII, No. 2.)

LEPIDOPTEROUS PESTS OF MAIZE IN TRINIDAD

BY

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Introduction

SCOPE AND OBJECT OF INVESTIGATIONS

The investigations described in this paper began in November 1941 and terminated in June 1942. They were started with the object of studying the habits and life history of *Laphygma frugiperda* (S. and A.) and *Heliothis armigera* (Hbn.) under Trinidad conditions, and to discover if possible why these species are normally less serious pests in Trinidad than they are in some of the northern islands and to see whether any control measures could be suggested. During December, 1941, when neither *Laphygma* nor *Heliothis* was present on the maize, it was noticed that many of the plants were attacked by the stem-borers *Diatraea lineolata* (Walk.) and *D. saccharalis* (Fab.), and as these pests were obviously doing considerable damage it was decided to study them also.

Investigations were almost entirely confined to the farm of the Imperial College of Tropical Agriculture, where there was an area of several acres under maize. They were carried out on crops sown in early October and early December, and do not therefore include the main crop, which is sown in June. In spite of these limitations however, it is hoped that the results will be at least of some value, and possibly pave the way for further study.

TECHNIQUE

In the field general observations were made on the life history and damage to the crop, and these were supplemented at intervals by systematic counts. These counts were made by means of a modification of the method recommended for use in Britain by the Wireworm Survey. The method is to pace out the length of a side of the field which is at right angles to the drilling, and then to retrace one's steps for one-fifth of the distance. From the point reached pace 15 paces into the field along a drill-line, and take a sample, then take three paces sideways towards the centre of the field and 30 paces forward along a drill-line and take another sample. Sampling is continued in this manner until the opposite side of the field is reached, and is then repeated in the opposite direction so that the sample-lines are more or less parallel. In small or irregularly shaped fields the method can be modified by altering the number of paces mentioned above so that at least ten samples are taken. In the investigations on *Laphygma* and *Heliothis* the sample consisted of five yards of each of four adjacent rows in which each plant was examined. For *Diatraea*, where the stalks had to be split from end to end, 10 or 20 plants were taken from each station.

In the laboratory larvae of all three genera were reared to maturity in one pound jam-jars covered with a piece of glass and with ¼ or ½ in. of damp soil or sand at the bottom. A high humidity was found to be necessary, except for *Diatraea* larvae in the resting stage which lived for long periods under dry conditions. The food, consisting of leaves for *Laphygma*, pieces of cob for *Heliothis*, or lengths of stem for *Diatraea* was changed when it became mouldy. Only two or three larvae could be kept in each of the jars as all are to some extent cannibalistic, and with *Heliothis* it was found best to place only one in each. The moths of *Laphygma* were kept in pairs in paper-lined jars and fed on honey-water soaked up on cotton-wool; this had to be changed frequently as it tended to ferment. Eggs were laid on the paper and were removed daily.

ACKNOWLEDGMENTS

My thanks are particularly due to Professor A. M. Adamson for his helpful advice and interest throughout the investigations, and to Mr. A. Pickles, Entomologist to the Department of Agriculture, Trinidad for helpful criticism and much information about maize pests in the island. I am also grateful to Mr. R. G. Fennah, Entomologist of the Food-crop Pests Investigation in the Windward and Leeward Islands, for information about conditions in the other islands. I am indebted also to the management of the College farm for their kind co-operation, and to Dr. C. F. W. Muesebeck of the United States Bureau of Entomology and Plant Quarantine and Dr. C. H. Curran of the American Museum of Natural History for the identification of insects. And finally I wish to thank Miss P. Atteck who helped with the preparation of the figures.

Laphygma frugiperda (Smith and Abbot)

This species is well known as a pest of corn in North, Central and South America as well as in the West Indies, and appears to be exclusively a New World insect. Among the English-speaking peoples it is usually called the Fall Army Worm because of its annual move northwards in the United States during the autumn. It attacks a very large number of plants including crop-plants, and has been recorded from such widely differing crops as apple and rice. Luginbill (1928) lists 58 host-plants, and mention of others may be found in the literature. In the West Indies, and in Trinidad in particular, it is well known as a pest of corn, and is said almost to prevent its cultivation in some of the Lesser Antilles.

The present investigations were made in a year during which there was no serious outbreak, and Mr. Pickles informs me that during outbreaks

conditions are somewhat different as the insect attacks most grasses and sugar cane as well as corn, which it frequently destroys. The following data and conclusions apply therefore only to conditions during a normal year.

Most of the work on this species has been done in the United States, where it is endemic in Florida and southern Texas, and moves northwards every summer in successive waves reaching as far as the Canadian border, being killed off every year by the cold weather. Luginbill (1928) has given excellent descriptions of all stages of the insect and Vickery (1929) has described its habits under the sub-tropical conditions of Texas; both these authors have reared large numbers of parasites.

In Trinidad during the investigations the larvae were found almost entirely on corn, only the leaves of young plants being damaged, and as soon as the tassels began to form the attack ceased (fig. 1). In the opinion of several corn-growers in Trinidad, and of the author, such an attack in no way affects a healthy crop despite the fact that it looks serious at the time. Plants which have been adequately manured and cultivated grow away very rapidly, and within a remarkably short time all signs of damage have disappeared. During an outbreak, however, the attack may be continuous and the bud and even the young stem may be destroyed, the plant being killed. Observations were made in the field and the insect was reared through its entire life cycle in the laboratory. The observations were found to agree closely with those made in the United States, especially with those of Vickery in Texas.

The Egg

Eggs are laid at night in clusters in or near the "throat" of young corn-plants when they are between one and three feet high. They were usually found on the upper surface of the leaves in clusters of from 40 to several hundreds, but Mr. Pickles informs me that during outbreaks the eggs are often laid on weed-grasses. The clusters are formed of successive layers of eggs intermingled with hair-like scales from the body of the female and are usually greenish or brownish; in a cluster of several hundreds there may be as many as six layers. The incubation period was found in the laboratory to be two days for 21 clusters and three days for 37 clusters. This period is probably equally short in the field, because at no time was it easy to find clusters on the leaves even though they are quite conspicuous.

The Larva

As soon as the larvae hatch they eat their egg-shells, and after a few hours start to feed on the leaf. The first instar always skeletonises the leaf leaving the epidermis on one side and the second and third may do so also if the leaf is old and hard. After a few days the larvae migrate into the "throat" of the plant, and there pass the rest of their larval life feeding on the young rolled up leaves. While in the "throat" the larvae are antagonistic and will fight, kill and eat one another, so that rarely more than one survives in any one plant. Little is known about dispersion of the larvae from one egg-cluster, but it does not appear to occur extensively if food is available, because

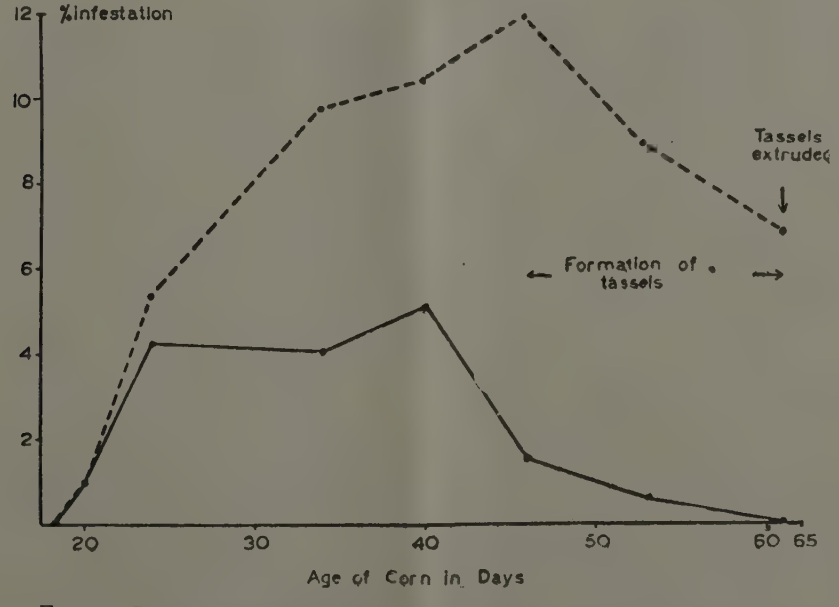

Fig. 1.—Graph showing the course of infestation by *Laphygma frugiperda* of corn planted on the College farm on 5th December, 1941. The continuous line represents the percentage of plants containing larvae and the dotted line the percentage of plants showing damage.

one large larva, presumably the sole survivor of an egg-cluster, was often found in an area of otherwise uninfested corn. Large larvae may, however, migrate from one plant to another for no apparent reason, and young larvae hatched in the laboratory were found to walk great distances and overcome barriers in their search for food.

The length of larval life is from 14 to 25 days, each of the 6 or 7 instars occupying 2 or 3 days with the exception of the last, which is longer because the prepupal stage is included in it. Shortly before pupation the larva burrows into the soil, and forms a small ovoid pupal chamber from one to three inches below the surface. It then becomes a prepupa, which stage is well marked, the larva being incapable of any movement other than jerking the body from side to side. After two or three days pupation occurs.

The Pupa

The pupal stage in the laboratory lasted 8 to 11 days, and emergence usually occurred at night.

The Moth

The moths show marked sexual differences in coloration, the female being more drab than the male. Their habits are cryptic, and few specimens, all of them males, have been taken at lights. Occasionally females were found on the soil against which they were almost invisible. The following observations were made in the laboratory.

Mating occurs at night one or two nights after emergence, and one to three days after emergence egg-laying commences. Eggs are laid at night, and one to seven clusters are deposited each night for two to six nights (Table 1). Each female produces over 1,000 eggs and may produce over 4,000. Because, however, of the cannibalistic habits of the larvae it seems that the number of egg-clusters laid rather than the number of eggs is the more important in deciding the ultimate number of offspring. The length of life of the two sexes was about the same (Table 1), being three to eight days, and one male appeared capable of fertilising at least two females. The sexes occur in about equal numbers but females tend to emerge earlier, and are therefore more abundant than the males at first.

Infestation of Maize

In Trinidad the larvae were found almost exclusively on maize during the investigations, but they have often been recorded on other grasses in other years. It is probable that the species is widespread on the island but has normally only a small population, and that when an area of corn is planted gravid females are attracted to it from considerable distances.

When these investigations began in October 1941 two fields on the College farm had October-sown corn on them, and many larvae were present. By mid-November the infestation had reached 58 per cent. on field 2 and 53 per cent. on field 21. At the end of the month, when the tassels were produced, the infestation had vanished, and only two larvae were found in field 2, both in backward plants. Weekly counts of infestation and damage on the December-sown corn (fig. 1) showed that

TABLE I

Serial No. of pair.	Length of male life.	Length of female life.	No. of days before laying.	No. of egg-clusters laid on each following day.						No. of clusters.	Total No. of eggs.	Av. No. eggs-cluster.
				1	2	3	4	5	6			
1	7	5	3	7	1	—	—	—	—	8	1,659	207
2	3	7	3	4	1	1	1	—	—	7	2,211	316
3	5	7	2	3	3	2	2	1	—	11	3,348	304
4	7	5	2	1	1	—	—	—	—	2	1,537	768
5	2	8	1	2	2	2	1	1	2	10	2,451	245
6	4	7	1	4	2	1	1	1	1	10	4,963	496
7	7	3	1	1	2	—	—	—	—	3	2,247	749
8	8	7	2	2	2	1	—	—	—	5	2,195	439
9	4	8	1	1	1	1	2	—	—	5	1,559	312
10	4	6	2	2	1	1	—	—	—	4	1,313	328
Av. ...	5.1	6.3	1.8	—	—	—	—	—	—	6.5	2,348	361

Table showing the lengths of life of the two sexes, time of laying and number of egg-clusters and eggs laid by individual pairs of *Laphygma frugiperda* in the laboratory.

the number of larvae increased rapidly at first and fell off as soon as the tassels began to develop (there would probably be a steeper fall during a heavier infestation), and that larvae were present for only about one month, which is little more than the length of one generation of the insect. The species was therefore unable to maintain a population on the corn, and all the eggs must have been laid by females from elsewhere.

At no time were larvae found on corn in full tassel or later, although a few specimens were found feeding on the young unopened tassels to which they did little damage, merely removing the tips of the panicle. Similarly in no plant was the bud found to have been destroyed. This is in contrast to the conditions during an outbreak and in other places, such as the United States and some West Indian islands, where whole crops are eaten to the ground, the larvae marching off in hordes to new feeding-grounds.

Natural Enemies

Predators of *Laphygma* larvae in Trinidad include the Kiskadee (*Pitangus sulphuratus*), the Tick-bird (*Crotophaga ani*) and the Boat-tail (*Quisqualus lugubris*) and wasps of the genus *Polistes* (Jack Spaniards). Four parasites were found: these were the Tachinid flies *Archytas piliventris* V. d. W., *A. plangens* (?) and *Winthemia* sp. and the Ichneumonid wasp *Eiphosoma* sp. Only *A. piliventris* was obtained in large numbers, the other species being apparently of minor importance.

From 115 *Laphygma* larvae collected in November 1941, 58 adults were reared and 21 specimens of *A. piliventris*, the rate of parasitism being 18 per cent. Luginbill states that this species is a parasite of *L. frugiperda* in Texas and that it is larviparous; this fact was not verified in Trinidad. The puparium is found in the pupa of the host and can easily be detected from outside as it lies in the thorax of the pupa, behind which appears a constriction. The flies emerge, one from each host, a few days after the moths would have appeared. If, as is possible, this parasite is not present in some of the Lesser Antilles that suffer severely from the depredations of *Laphygma*, it might be worth attempting to introduce it. That it does, however, occur in at least one of these islands is indicated by the presence of a specimen from St. Vincent in the College collection reared from *L. frugiperda* by F. A. Squire in 1936. In Texas Luginbill states that it shows a rate of parasitism of from 5 per cent. to 20 per cent., and during the slight infestation on the December-sown corn on the College Farm it showed only 4 per cent. It might reach a very high figure amongst a dense population such as appears to occur during outbreaks.

Control

From the above observations it seems that control of *Laphygma* in normal years in Trinidad is not necessary if the crop is well manured and cultivated. During outbreaks, however, dusting is practised in some places with lead arsenate or with a mixture of lead arsenate, derris and sulphur, but this can hardly be used under conditions of peasant cultivation. With regard to other West Indian islands where damage is serious, as stated above the introduction of *Archytas piliventris* might prove beneficial if this species is not already present. In other parts of the Americas various methods such as dusting, spraying, baiting, flooding and the mechanical destruction of the larvae on the move have been advocated for various crops.

Heliothis armigera (Hübner) =*obsoleta* (Fab.)

The Corn-ear Worm or Cotton-boll Worm is a pest of many crop-plants throughout the tropical, sub-tropical and warmer temperate regions of the world. It is a serious pest of corn in many of the Lesser Antilles, but in Trinidad, although most crops of corn seem to be slightly damaged, *Heliothis* appears to be of minor importance. It was not found on cotton in Trinidad during 1942, and in 1941 only one specimen was found in 34,747 bolls from the College farm which were examined for a Boll-worm, *Sacadodes pyralis* Dyar, by Dr. E. M. McC. Callan, to whom I am indebted for this information. It was, however, found attacking ochro and tomatoes, but the damage was not serious.

In the October-sown corn on the College farm an hour's search revealed only two larvae in the cobs, but in the December-sown crop, which matured during the dry season, 55 per cent. of the cobs were attacked, the damage being confined to the destruction of a few grains at the tip. Undetermined beetles and small dipterous larvae were found in some of the damaged cobs, but as these were present in other cobs also their presence cannot have been entirely due to the tunnels made by the caterpillars. During the wet season the injury to the cob may perhaps become more serious, because the tunnels made by the larvae might allow access to water and fungi, which together are responsible for an increase in the damage done in the United States and the islands to the north. Damage to sweet corn grown for local consumption might perhaps prove serious as the larvae render the cob unsightly. In Trinidad the larvae were not found damaging the leaves like *Laphygma*, as occurs in the United States, but did not appear on the crop until the silk was extruded.

Brief observations in the field suggested that the life history of *Heliothis* in Trinidad is similar to that described by Phillips and Barber (1931) in the United States. The life cycle probably occupies three to four weeks, and only one generation appeared to be passed on each crop. This means that, as with *Laphygma*, there is no building up of population on the corn and that the moths responsible for the infestation are bred on some other plant. Corn planted in January and grown by means of irrigation during the dry season was also attacked, which indicates that adults are available during the dry weather to lay eggs on any corn producing silk.

In view of the slight damage done to field corn in Trinidad control does not appear to be necessary. Many methods have, however, been recommended in United States, some of which could apply here, particularly if it is desired to grow sweet corn on a garden scale. These are desilking the cobs to prevent oviposition and remove any eggs already laid, applying insecticides and mineral oils to the silks, and poison-baiting the adults ; these methods are probably too expensive for commercial use. Other methods such as winter cultivation to destroy hibernating pupae cannot apply to Trinidad conditions, but the suggestion made by several workers that varieties of corn having long tight-fitting husks be grown is probably most satisfactory. This would encourage the larvae, which are cannibalistic (Barber 1936), to fight and eat one another in the narrow silk-channel, and the survivor would be able to complete its development by feeding on the larger volume of silk in the longer channel, and so would not damage the grain on the cob. It is noticeable in the field in Trinidad that ears with short loose husks are always more severely damaged than those with long tight-fitting ones, because there is not so much silk and the larvae can move more freely and so damage a larger number of grains.

Parasites do not appear to exert much control on this pest. *Trichogramma minutum* Riley, an egg-parasite, is recorded from it in the United States, and this species is known to occur as a parasite of other moths in Trinidad. Unless, however, every egg on each cob were parasitised there would be a larva per cob and the damage would be unchecked. In Trinidad the Sarcophagid fly *Sarcodexia sternodontis* Towns. was reared from two of 64 larvae collected when nearly full-grown, there being four specimens from one and one from the other. The larvae of this parasite left the caterpillar after if had burrowed into the soil to pupate, and pupated themselves in the soil.

Diatraea spp.

This Pyralid genus contains many species, most of which are found in the New World, and many of which cause damage to crops by boring in the stems of the plants, which are weakened and easily broken by wind or cultivation. In December 1941 the October-sown maize on the College farm was found to be heavily infested and considerable damage was being done.

Study of the literature revealed that two species, *Diatraea saccharalis* (Fab.) and *D. lineolata* (Walk), had been recorded from maize in Trinidad (Box 1935), but that no study of the problem had been published. *D. saccharalis* is widespread in the warmer parts of the New World, and is best known as a pest of sugar cane. It is found in a wide range of food- lants and in many cultivated grasses. *D. lineolata* is confined to the Neotropics (Davis, Horton *et al* 1933), and feeds almost entirely on maize (Box 1935 and Myers 1935) ; Fitzgerald (1935) has, however, recorded it from teosinte (*Euchlaena mexicana* Schrad.), but as this imported grass is only grown on an experimental scale on the island it need not be considered as an alternate host. In the United States *D. saccharalis* attacks corn, but other species such as *D. grandiosella* Dyar and *D. zeocolella* Dyar (=*crambidiodes* (Grote)) are more important (Davis, Horton *et al* 1933 and Ainslee 1919), and have been thoroughly investigated. The literature on the genus is therefore extensive, but there is little published about *D. saccharalis* in corn or about *D. lineolata.*

Species Determination

The first problem was therefore to find which species was causing the damage on the College farm. All the larvae had yellow heads and, as it is well known that *D. saccharalis* larvae have dark brown heads in sugar cane, it was at first thought that all the larvae were those of *D. lineolata.* Rearing of the adults, however, showed that the species were mixed, although *D. lineolata* appeared to be far the more common. Unfortunately the corn was drying rapidly in January and because, as is shown below, this induces a marked change in the specific ratio, it was not possible to find the exact ratio, nor was it possible to find a means of distinguishing the larvae. Heinrich states that he is unable to separate the larvae of *Diatraea* in corn in the United States (Holloway, Haley *et al* 1928).

Life History

A few notes were obtained on the life history of *D. lineolata* during the initial period of the investigation, but they are not extensive as it was not possible to make many field examinations without doing considerable damage to the crop. The eggs, which are flat and overlap like tiles on a roof, are laid on the leaves, and are white at first, soon acquiring two or three irregular transverse red bands. After three days hatching occurs, and the larvae feed on the leaf which they skeletonise like *Laphygma.* They then walk down the leaf and after feeding on the leaves round the tassel or on the tassel itself they bore into the stem. The length of larval life in the living corn was not determined but appeared to be four to six weeks. The larvae bore continuously in the stem, although it appears that they may leave and re-enter elsewhere as empty burrows are often found. At intervals a hole is made to the outside and the frass is pushed out ; these masses of frass are often very conspicuous. When the time for pupation arrives the larva makes a chamber lined with silk, and cuts an exit-hole to the outside, leaving only a thin membrane which the moth can push off between itself and the outside air. Pupation occurs in the chamber, and after about 10 days the moth emerges. The exit-hole from the pupal chamber is not a constant feature, and the moth often emerges from the last frass-hole. In the dry stalks the larvae went into a resting stage ; this is dealt with in a later section.

Damage to Maize

It is difficult to evaluate the damage done by a stem-borer because it is not possible to assess the loss of vigour sustained by the plant.

Of the October-sown corn, however, 22.9 per cent. had broken off about one foot above ground-level, and of these plants only about one-quarter produced cobs which were fit to harvest. As these plants fell fairly late in their development, when the cobs were getting heavy, the neighbouring plants can be presumed not to have benefited by their absence and they can be regarded as total loss. Also even in plants which did not fall the damage to the conducting tissues was considerable, and as 95.8 per cent. of the plants were found to have been attacked the loss of crop must have been great; 20 per cent. is a very conservative estimate. This isolated attack may have been a particularly heavy one, but there is no reason to presume this, and even a quarter of the damage is sufficiently serious to warrant that attention be drawn to it, especially as the damage is of a kind not readily observable by the farmer or peasant. The December-sown corn was much less damaged, but this may be a constant annual feature because, as is shown below, the borer can and does carry over in the stalks of the October-sown corn until the arrival of the rains in May. The October-sown crop is the one which one would expect to be the more heavily attacked as it is a matter of general knowledge that most insects are more active in wet weather in Trinidad.

Damage occurred to the cobs of the December-sown corn, but it was very slight, only two per cent. of them containing larvae of *D. saccharalis* which destroyed a few grains on each cob. Similarly there being only one or two larvae boring in the stem of each of a small percentage of the plants, as opposed to five or six in each of over 95 per cent. of the plants in the October-sown crop, loss of crop cannot have been important. Only a few plants in the acre examined had fallen.

Resting Stage of Larvae

The larvae in dry corn stalks in dry weather go into a resting stage analogous to the condition of hibernation in temperate climates. The term diapause has not been used here to describe this phenomenon because although the larvae do not develop at the usual rate they remain active and moult and may grow somewhat during the period of quiescence. This condition could perhaps be described as a phase, because the larvae are morphologically distinct from the normally developing form, being uniformly butter-yellow without the normal black spots of the genus. In the United States where the same phenomenon has been observed in other species the term hibernation has been used as it occurs in the winter, but this cannot apply to the tropics, neither can the term aestivation which has a definite reference to summer. Perhaps it will become necessary at some time to produce a term for this phase-change which is apparently prevalent in the large genus *Diatraea* and may occur in other Lepidoptera also.

The phenomenon of hibernation, which is similar to the dry weather resting stage in Trinidad, is well known in species of *Diatraea* in the United States, and is described for *D. saccharalis* (Holloway, Haley *et al* 1928), *D. zeacolella* (Ainslee 1919) and *D. grandiosella* (Davis, Horton *et al.* 1933), the last two passing the winter in the tap-roots of corn below ground-level. No reference to a larval resting stage of this genus in the tropics has been found; although Tucker (1935) mentions pupal diapause of *D. saccharalis* in sugar cane in Barbados; no similar phenomenon was found in corn in Trinidad. The American workers all note that the hibernating larvae are without the typical black spots over the body, and are uniformly butter-yellow. This was also noted in Trinidad, although here the cessation of development was not due to a drop in temperature, which is presumably the cause in the United States.

After the October-sown corn had been harvested on February 1st it was found that 36.1 per cent. of the dry stalks still contained larvae, and that pupae were rare. These larvae were usually present singly in each stalk, but some stalks contained as many as four, the average being 1.36 per stalk. All these larvae were butter-yellow without spots, and all had yellow heads. It was unknown at the time which species they represented, but when later adults were obtained they were all found to be *D. lineolata.* Observations and counts were made throughout the dry season and fig. 2 shows the number of larvae and pupae that were found per 100 stalks. It can be seen from this figure, which also shows the rainfall, that there were only very few pupae at the beginning of the dry period, and then none at all until a rainy period at the end of April, when a considerable number appeared. These pupae took only about 10 days to emerge, and therefore the number at the beginning of June was again low, there being only a few larvae left to pupate after the first lot.

While in the resting stage the larvae fed on the dry pith and moulted several times in the laboratory, and those that were small at the beginning grew slowly to full size and then continued to moult; there was evidence that the same occurred in the field. No larvae less than three-quarters grown were found among those that had gone into the resting stage. These observations resemble the findings of Davis, Horton *et al.* for hibernating larvae of *D. grandiosella.*

It was expected that the rains would cause termination of the resting stage and, following on the work of Squire (1937), who found that diapause in *Platyedra gossypiella* Saund., the Pink Boll-worm, was controlled by humidity and the food eaten shortly before, an attempt was made to find the controlling factors for *Diatraea.* Sixty resting larvae taken from the field in April were placed in pairs in 1 lb. jam-jars with glass tops and ½ in. sand at the bottom. One group of 10 jars contained dry corn-stalks and damp sand, the second dry stalks and dry sand, and the third fresh green stalks and dry sand. The larvae were examined at weekly intervals, and table 2 shows that none of the seven surviving larvae in group 2 pupated, whereas most of those in groups 1 and 3 pupated within three weeks. This experiment,

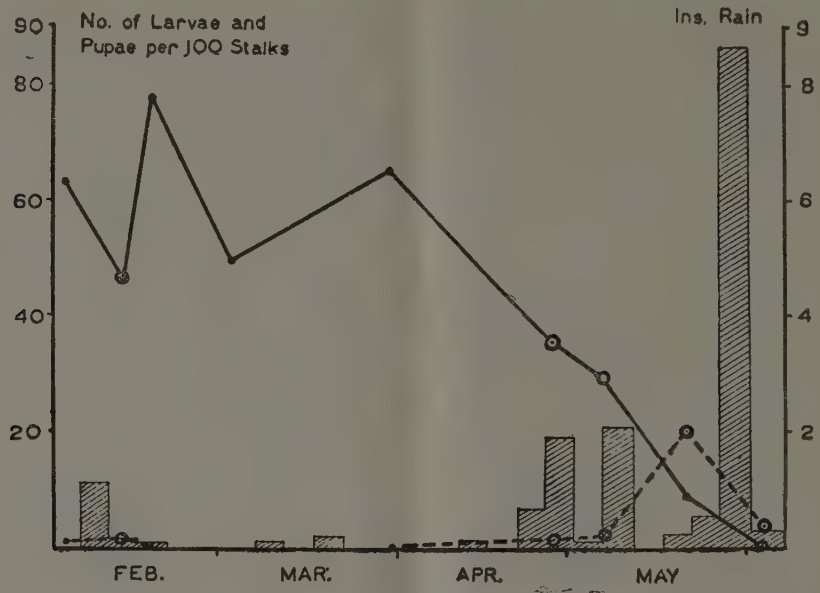

FIG. 2.—Graphs showing the number of resting larvae (continuous line) and pupae (dotted line) of *Diatraea lineolata* found per 100 dry corn-stalks during the dry season. The histogram shows the rainfall over the same period as recorded at the College Meteorological Station grouped into 5-day periods. Points enclosed in a small circle are readings from field 21 on the College farm, and all other points are readings from field 2.

though conducted on a small scale, shows that high humidity in the stalks can induce pupation, and supports the conclusion that pupation in the field is induced by rain. The fact that the larvae in the fresh green stalks pupated earlier than those in the damp stalks suggests that dry food may be a factor in the initiation of the resting stage.

TABLE II

Date of examination	No. of larvae which had pupated		
	Dead stalk wetted	Dead stalk dry	Fresh green stalk
15 Apr. ...	2	0	8
24 Apr. ...	3	0	3
30 Apr. ...	2	0	1
7 May ...	3	0	0
14 May ...	0	0	0
21 May ...	0	0	0
28 May ...	0	0	0
Total ...	10	0	12
No. of larvae which died ...	7	13	7
No. of larvae which remained alive	3	7	1

Table showing the number of resting larvae of *Diatraea lineolata* which pupated out of each batch of 20 kept in different environments after April 8th, 1942. See text for further explanation.

It has been suggested that the resting stage lasts for a definite time, but the above experiment produced pupae weeks before there were any in the field, and larvae kept in the laboratory under dry conditions since March still show no signs of pupating at the time of writing (June) after all those in the field have pupated and emerged.

The moths from these resting larvae are active and appear some three weeks or more after the beginning of the rains at a time when young corn is available for oviposition. If they appeared earlier they would find no corn on which to oviposit. The presence of dry corn-stalks during the dry season is therefore almost an essential for the survival of this pest in Trinidad and their destruction should go a long way towards controlling it. This subject is more fully discussed in the section on control.

PARASITES

Many parasites of *Diatraea saccharalis* are known; the Tachinid flies *Lixophaga diatraeae* Towns., *Metagonistylum minense* Towns., and *Theresia claripalpis* V.d.W. have been widely introduced into the sugar-cane growing areas of the Caribbean region, and the egg-parasite *Trichogramma minutum* Riley has been used for mass-liberation in Barbados. Parasites of this species recorded from Trinidad in the literature include *T. minutum*. *Prophanurus* sp., *Cyanopterus* sp., *Apanteles* sp., *Paratheresia* sp. and *Stomatodexia* sp. Little, however, is known of the parasites of *D. lineolata*.

Scarramuzza (1940) was unable experimentally to rear *T. claripalpis* in this species but succeeded earlier with *L. diatreae.*

During the present investigations no egg-parasites were found, probably because only a small number of egg-clusters was found in the field. The empty puparia of the Tachinid fly *Paratheresia braziliensis* Towns. were, however, frequently found in the burrows in the dry stalks, and a few live ones were found early in the dry season and reared; they represented a parasite rate of less than 5 per cent., and it is unknown which species of *Diatraea* they parasitised. Clusters of empty cocoons of the Braconid wasp *Apanteles diatraeae* Mues. were also fairly frequent in the dry stalks, and this species was twice reared from *D. lineolata* in the dry season; it appeared to be in a resting stage with its host. It is probable that some of the clusters of empty cocoons had been produced earlier from *D. saccharalis* larvae in the living corn. The parasite rate cannot greatly have exceeded one per cent. From these observations it appears that parasite sexert very little control over *Diatraea* in corn in Trinidad.

Control

Apart from the attempts at biological control mentioned above, cultural methods against hibernating larvae in corn-stalks have been tried with success in the United States (Davis, Horton *et al.* 1933 and Ainslee 1919), and it is suggested that similar measures be taken in Trinidad. Such measures would not greatly affect *D. saccharalis* which can breed continuously in the large sugar plantations of the island and fly to each fresh crop of maize, but they should go a long way towards exterminating *D. lineolata,* which can only breed in corn and in teosinte in the few places where it is grown, and which appears to be the more injurious species. It is strongly recommended that some time during the dry season, preferably a few weeks before the onset of the rains, all dry corn-stalks should be destroyed or treated to kill the resting larvae. This should practically eliminate *D. lineolata* from all areas except those, such as the Nariva swamp, where corn is grown in the dry season. The present practice of peasants and others of leaving the stalks to "shade the land" or to use as bean-sticks when the rains come should be discouraged.

It has been suggested that shading of the land during the dry weather is essential to prevent burning up of humus and loss of soil texture; it is also said to prevent weed-growth. This may be true, but it is simple to demonstrate that old corn-stalks do not perform these functions. That weed-growth is not prevented was demonstrated by the fact that field 2 on the College farm became so weedy by April that it had to be cleared, and that the presence of the stalks in no way alters the effect of the sun on the soil was shown by means of a recording soil-thermometer which showed no appreciable difference between the temperatures reached by the soil surface during the day on a cleared area and on an area under standing stalks. The presence of dry corn-stalks on the land during the dry season cannot therefore be regarded as a means of providing shade, and there is no adequate reason for leaving them there.

The problem of disposal of the stalks in a way that would both destroy the resting larvae in them and retain the organic matter for incorporation into the soil as manure was found fortunately to present few difficulties. It was thought at first that it would be necessary to burn them, but experiments showed that the making of pen-manure out of the stalks could, if the normal procedure be slightly modified, kill 100 per cent. of the resting larvae and leave the stalks for use on the land as manure. Some stalks were put for 14 days into the ox-pen on the College farm, and were then piled in the normal manner to be left to rot. At this stage about 50 per cent. of the larvae had been killed by trampling or drowning, and a few days later the centre of the heap became a rotting mass in which no larvae had survived. Ten days later larvae could only be found in the dry stalks on the surface of the heap. It is apparently not usual, and expensive and wasteful to turn these heaps of pen-manure; but if the dry top layer could be incorporated into the body of the heap about 10 days after removal from the pen all the larvae would be killed.

Discussion

These investigations, despite their cursory nature, have shown that there is at least some hope of reducing the damage done by lepidopterous pests of corn in Trinidad, and have pointed to possible methods of controlling *Laphygma* and *Heliothis* in the Lesser Antilles. As no investigations of the damage done by *Diatraea* spp. to corn were made in the other islands, or indeed outside the small area of St. Augustine in Trinidad, no recommendations can be made for the other islands.

Laphygma frugiperda is evidently of no importance in normal years in Trinidad as long as the corn is well manured and able to grow away after the attack. During an outbreak, however, it may be serious on corn but can apparently be controlled on this and other crops with arsenical dusts. These investigations have merely indicated that the introduction of the parasite *Archytas piliventris,* which is common in Trinidad, into the islands to the north might be expected to have a beneficial effect if it is not already present.

Heliothis armigera also is not serious in Trinidad and might be controlled in the Lesser Antilles by growing varieties of field corn with long tight-fitting husks, as has been demonstrated in the United States. Sweet corn grown on a garden scale can be de-silked at two- or not more than three-day intervals and this should prevent infestation; it may also be possible to grow a long-husked variety of sweet corn.

The problem of *Diatraea* in corn is in need of much further investigation. It has been established that *D. lineolata* is an important species,

and that it passes the dry season as resting larvae in the dry stalks, and also that these larvae can be destroyed by making pen-manure a few weeks before the onset of the rains. Investigations are needed, however, to find out if it is of annual occurrence that the December-sown crop is less attacked than the earlier sowings, because this might have important agricultural consequences; and to find how far *D. saccharalis*, which having other important food-plants would not be controlled by destruction of plant residues, is involved in the attack. Present data indicate that *D. lineolata* is the more important species, but this is in need of confirmation, preferably over several cropping periods.

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NATURAL AND ARTIFICIAL FERTILIZERS*

THE agricultural application of calcium carbide (Copisarow, *J. Soc. Chem. Ind.*, 1941, 60, 245) raises the interesting problem of differentiation between natural and artificial fertilizers. The contrast extends beyond the colloidal and nutrient properties of the all-embracing humus and lies in the physiological function of certain organic compounds and complexes contained in the soil.

These substances include (1) growth-promoters, accelerators or proleriferating agents such as plant and animal sex hormones, phytohormones, alkylamines, pyridine bases, and others which in association with vitamins (pantothenic and nicotinic acids, biotin), and enzymic activity become growth regulators and (2) growth-protectors such as allantoin, urea, lysozyme or inhibin, maleic acid, alkaloids, glucosides, and so on. Some indication as to the wide distribution of the active principles generally associated with the natural fertilizers may be gathered from the fact that vitamin—B1 and its moieties, thiazole and pyrimidine, as well as biotin were found to be present in the soil to a depth of 8 feet.

Whilst it is as yet difficult to assess adequately the range and scope of the protective constituents or products of organic life, their significance both in growth and propagation cannot be exaggerated. So the wide distribution of the inhibitory or protective agents in the animal and plant world, their bactericidal, fungicidal, and antivirus properties, the transition of some of them into growth accelerators (maleic acid to ethylene), and their ultimate incorporation in the soil make them an essential factor influencing new growth.

Dealing with one of these agents we find that the wound-healing characteristics of urea closely linked with its antiseptic properties, its anti-virus activity as demonstrated in the case of tobacco mosaic and yellow fever virus, and extending to other physiological functions such as increased germination and specific action on gymnoplasts, make urea much more than a mere source of nitrogen. It becomes an essential factor in all natural fertilizers and represents the basis of the Indore process of manure-preparation. We thus perceive that the combined effect of the growth-promoting and protective agents in the humus, in conjunction with the activity of nitrogen-fixing bacteria and possible fungi, leads to the general well-being of the new plants, both by improved nutrition and disease-resistance. In this respect, the environmental influence of the remains of past organic life, as modified by the micro- and macrobiology of the soil in determining or influencing form and function of the emerging new growth is reminiscent of and certainly complementary to the heredity-influences occluded in the seed (genes and chromosomes) of the chemical orientating force exercised in the organizer cells.

Turning our attention to humus as a product of organic catabolism, we may regard it as linking the past with the present and representing in its condition a naturally-regulated equilibrium between supply and demand, not only of the wide

*Article by M. Copisarow, reprinted from *Chemistry and Industry*, **61**, No. 6, p. 67, 1942. All references have been omitted.

range of nutrients (including the energy-giving carbohydrates), but also of the available colloidal matter in the form of silicic acid, whose function is both structural and protective. Proteins, tannins, and lignin are the main inert organic contributors to humus. The decomposition of proteins gives aromatic amino-acids and heterocyclic products, which are easily transformed by the action of oxidases into dark-coloured products possessing all the characteristic properties of humic acid. One of the most important factors in humification (especially of lignin) is ammonia, whose influence increases the velocity of the oxidation-processes of the aromatic groups of lignin.

As to the ultimate fate of the physiologically-active soil constituents, they themselves undergo a series of chemical changes to be ultimately assimilated by the higher or lower organisms. The course of humus formation is not always one of mere degredation of active or inert complex substances to simple readily-assimilated bodies. So we find the degradation of proteins results in the formation of active phytohormones, the oxidation of which yields such substances as anthranilic acid and indigotin. Again, whilst cellulose and other inert bodies give on decomposition (among other products) active unsaturated hydrocarbons, these in their turn are oxidized in the soil to simple organic acids.

Within recent years a wide range of synthetic products has been evolved which seems to occupy an intermediate position in our differentiation of fertilizers. So we have a growing number of such products which either represent or substitute one or more not purely nutrient, but active constituents of humus. Among the former may be included urea, silicic acid, indolylacetic acid, and possibly vitamins, whilst among the latter we may place various aryl-aliphatic acids, calcium cyanamide, and calcium carbide.

It is interesting to note that, under conditions unfavourable to oxidation, growth-promoters and even certain plant and animal cells may persist for almost an indefinite period. So sterols are found in Peruvian guano, corals, and certain bituminous shales, in the latter of which they vary with the fossil-type, whilst œstrogenic substances were detected in the Dead Sea (end distant from the Jordan). The survival of plant and animal cells at low temperature over a considerable period is well demonstrated by the revival of lower forms of life found in the permanently frozen Siberian tundra. Again, neoplastic cells remain virulent after one year freezing to – 70°, whilst certain plant (bacteria, fungi, etc.) and animal (both normal and malignant) cells are not destroyed by immersion in liquid air or nitrogen.

INSECTICIDES DERIVED FROM PLANTS

From the time of the early Romans to the beginning of the twentieth century only three really dependable and important plant insecticides were discovered. They are tobacco, pyrethrum, and hellebore. The nicotine-insecticide industry has been developed largely in America, whereas the pyrethrum and hellebore industries are European in origin. During the nineteenth century there was little interest in searching for new insecticidal plants, but in the second decade of the present century large scale investigations were begun which finally led to a new world wide industry using *Derris* and *Lonchocarpus* as insecticide material. Even more recently anabasine derived from *Anabasis aphylla*, has become commercially important as an insecticide in the country of its origin, Russia, and Tephrosia is also used locally in a few places where it is easily obtained. For centuries a few countries, for example China, have had their own insecticides, but these have not become commercially important in other countries.

In view of all the work done on the insecticides of vegetable origin one might surmise that all the insecticidal plants have been discovered. Such is not the case. Further searches for suitable species should be continued, for this is yet an open field. Many books and papers give the names of dozens of plants poisonous to stock and other higher animals, very few of which have ever been tested as insecticides, and other publications give the names of scores of fish-poisoning plants most of which have never been tested as insecticides.

In the search for insecticidal plants there is no dependable guide. The only procedure is the trial-and-error method. One might surmise that botanical classification would be a trustworthy guide, but it is not, because hundreds of plant species must be examined to find one that is sufficiently promising to warrant a long series of intensive chemical and toxicological studies. This statement is well proved by an inspection of the hundred of species discussed which belong to the five families of plants producing the most important commercial insecticides. These five families and the insecticides derived from them are: Asteraceae, insect powder or pyrethrum; Chenopodiacae, anabasine; Fabaceae, derris, cube, and timbo; Liliaceae, hellebore; and Solanaceae, nicotine.

The search for promising insecticidal plants has been carried on by botanists, chemists, and entomologists for many years. The botanists have done valuable work in exploring the subtropics and tropics of Asia, Africa, and South America, and then publishing lists of poisonous plants, including those that might have insecticidal value. Botanists, chemists, entomologists, plant physiologists, and toxicologists should cooperate more than ever to find suitable insecticidal plants that can be introduced and grown in the countries in which insecticides are used on a large scale.—(From *Journal of Economic Entomology*, Vol. 35, No. 2.)

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Nitrogen Metabolism of Sugar Cane

As a result of investigations carried out in Hawaii it was found that protein was the chief nitrogen compound in the cane plant and the principal form in which nitrogen was stored in it. Two days after nitrogen was given to nitrogen-starved plants, a considerable amount of protein had formed in the roots, and 5 days later a very large amount of it had accumulated in all parts of the plant.—(*Brit. Chem. Phys. Abstrs.*, B.III, p. 322.)

* * *

Loss of Soil Nitrate

It was found in Georgia that even under extremely wet conditions most of the nitrate nitrogen in Cecil sandy clay loam remains in the surface of the soil within easy reach of the roots of crops, and there is very little loss of soil nitrate due to leaching from summer rains on the heavy red soils of the Piedmont. Under extremely dry conditions on at least two soil types there was an upward movement of nitrate nitrogen, which became concentrated in the surface inch.—(*53rd Annual Report of the Georgia Agricultural Expt. Station.*)

* * *

The Control of Nut Grass

The destruction of nut grass by tillage is based on the fact that most of the tubers are located in the upper six inches of soil. Based on tuber counts alone, results from ploughing at intervals of four weeks were as good as those from turning at shorter intervals; the final infestation records showed that ploughing at intervals of two or three weeks was better. A failure on a low area of poorly drained clay suggests that tillage should not be relied upon for eradication from areas likely to remain wet for long periods.—(*Soils and Fertilizers*, Vol. 5, No. 3.)

* * *

Utilisation of Husks on Coconut Estates.

Potash is the main manurial constituent of the husks. It is present in an easily soluble form and is dissolved out when open heaps of husks are exposed to heavy rains. Only small amounts of phosphate are present. When the husks are buried in the soil their moisture-holding properties are very valuable in times of drought, whilst their spongy structure provides a good medium for root development of the palms. Husks should not be burned to form a manurial ash unless stocks accumulate which cannot be buried in trenches. The latter is the best method of utilising husks, and the various methods of burying them are discussed.—(*New Guinea Agric. Gaz.*, 1941, 7, 134-138.)

Dried Poultry Manure

As a source of nitrogen, dried poultry manure is only about 2/3 as effective as sulphate of ammonia in its year of application. The design of experiments carried out at Rothamsted enabled residual and cumulative effects to be investigated but these turned out to be small, even when the dressings had been repeated for four years on the same plots. The experiments had special value in directing attention to the manurial responses given by market garden crops grown under normal commercial conditions, and also in developing the technique of estimating the yield of crops harvested on a number of successive occasions.

* * *

Soil and Seed Disinfection

Methods of soil sterilization suitable for use on native small holdings and gardens in Fiji are briefly outlined by B. E. V. Parham in the *Agric. J. Fiji*, 12 : 103-4. Steam sterilization is ruled out as being too difficult. *Fire.* Where wood is abundant sterilization by fire is commonly used by Chinese market gardeners. The amount o wood required is equal to a solid layer 3 inches thick. *Chemical Methods.* (1) Formalin. One gal. commercial formalin diluted with 100 gal. water applied at the rate of 10 gal. per sq. yard. The soil is covered immediately after application with sacks or dead grass to retain the fumes. Seeds or plants must not be put in till at least a fortnight after treatment. (2) *Bluestone.* One pound bluestone dissolved in 7 gal. water watered in as for formalin will eradicate the common pathogen, *Scelerotium rolfsii.* Apply at the rate of 2 gal. per sq. yard, or until the soil is wet to a depth of 6 inches. A few weeks delay before using the ground is necessary. *Chestnut Compound.* Valuable in controlling damping off of seedlings. It does not injure but rather stimulates growth of seedlings. The stock mixture consists of 2 oz. copper sulphate (Bluestone), 11 oz. ammonium carbonate (rock ammonia) ground separately before being thoroughly mixed and stored in a tightly stoppered jar for at least 24 hours. For use dissolve the mixture in water at the rate of 1 oz. to 2 gal. *Seed Disinfection.* Commonly used seed disinfectants are corrosive sublimate, formalin, hot water, copper carbonate, copper sulphate and proprietary compounds usually containing mercury. Directions for use are not given since specific treatments are required for various types of seed.—(*Horticultural Abstracts*, Vol. 12. No. 2.)

ERRATA

Vol. 19, No. 9 (September), page 166 : 2nd column, lines 32 and 46 : for mortgagors *read* mortgagees.